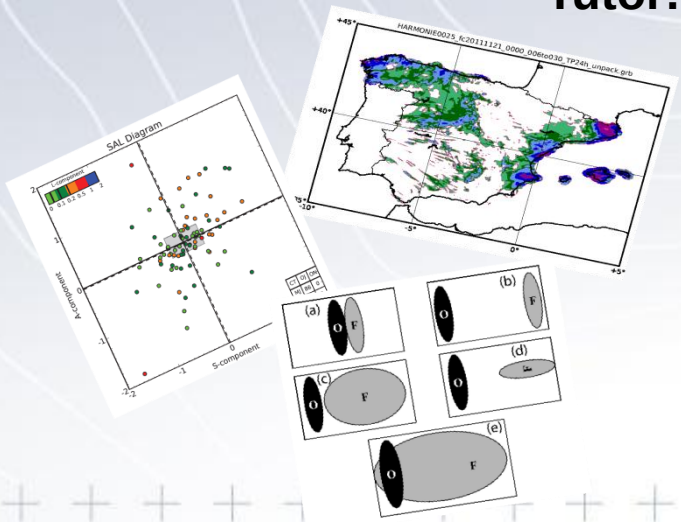
GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

Python interface for object-oriented verification methods: SAL

Proyect 13: Postprocess advanced methods and presentacion of products of ensemble predictions for the short range

Development and Applications Department (Madrid)

Tutor: Carlos Santos Burguete



Arancha Amo Baladrón

OUTLINE

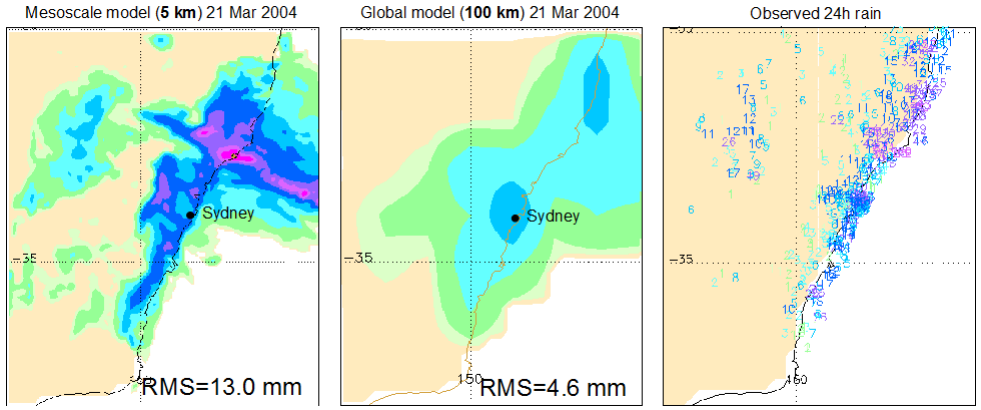
- New verification methods. Motivation.
- SAL (Structure-Amplitude-Location).
- Software design: python interface + fortran90
- Verified periods.
- Summary.

TRADITIONAL Vs. OBJECT-ORIENTED VERIFICATION METHODS

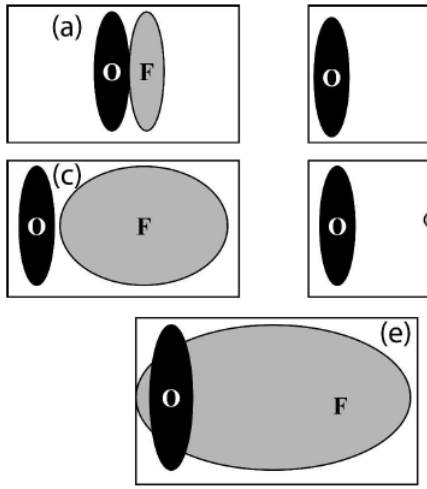
Traditional methods:

- Measures-oriented: matching forecast grid to an observation grid or set of points.
  Counts of fc-obs pairs (y/n) → contingency table → verification scores (RMSE,POD,FAR,CSI,…).
- No diagnostic information.
- No consistent with visual evaluation of forecast.
- Insensitive to differences in location, shape, and timing errors → **double penalty problem**

Which forecast would you rather use?



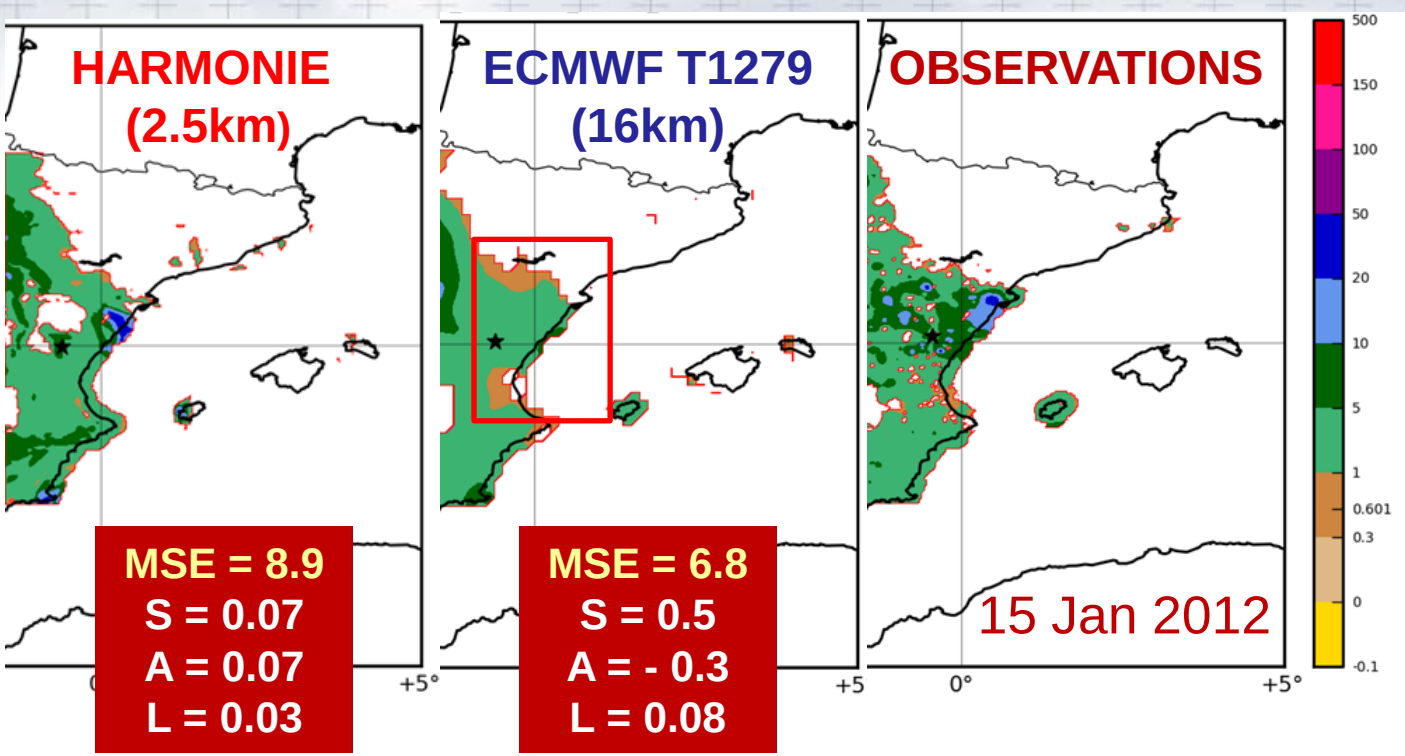
HIGH RESOLUTION MODEL ***LOW RESOLUTION MODEL*** ***OBSERVATIONS***

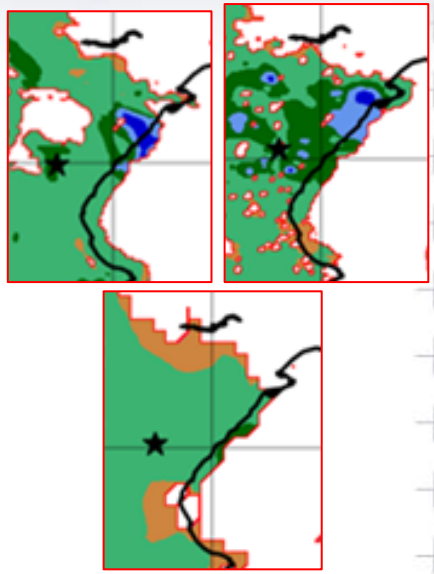


hit rate=0
but **A** is better!!!

hit rate > 0
E right shape ???

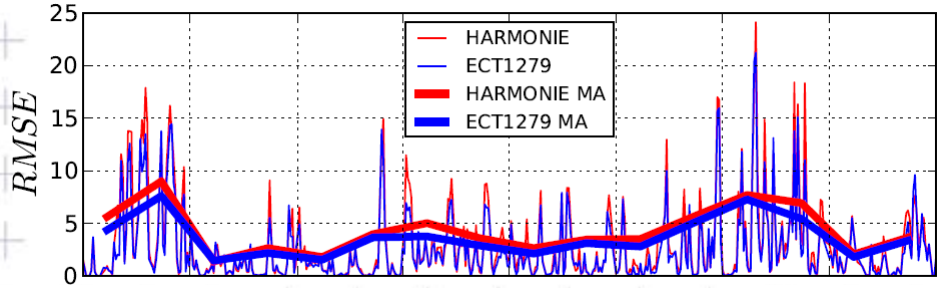
DOUBLE PENALTY PROBLEM





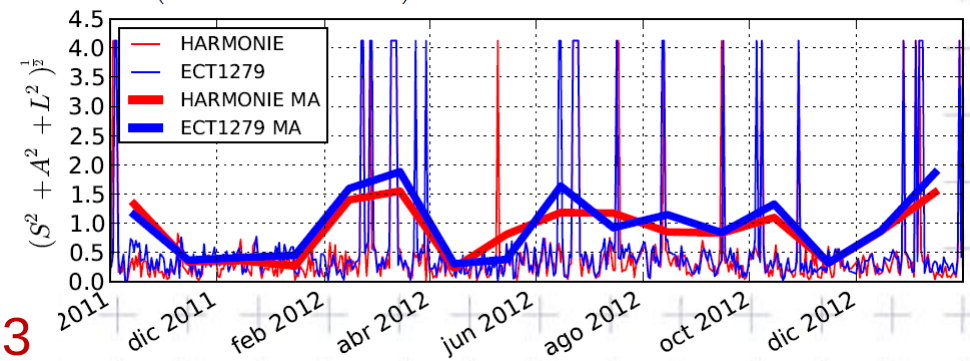
MSE, S, A, L = 0
perfect forecast

RMSE



Oct 2011

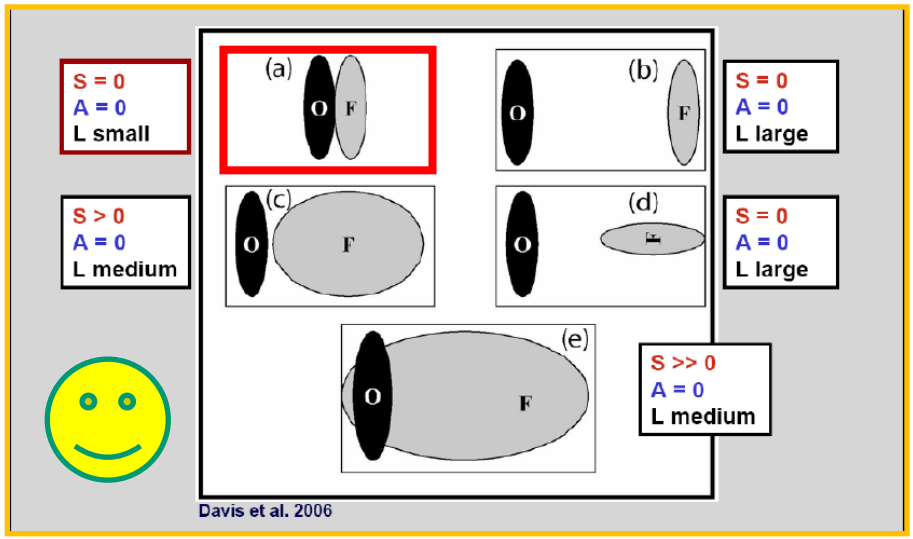
$\sqrt{(S^2+A^2+L^2)}$



Jan 2013

NEW VERIFICATION METHODS:
SAL (Structure-Amplitude-Longitude)

- Object-oriented verification methods are especially suitable for:
  - **high-resolution forecasts**
  - highly **localized** and **episodic phenomena** → **rainfall**
- Based on the identification of coherent and contiguous **entities** with characteristic **attributes**



S-shape and size **A**-total amount of pcp
L-pcp distribution

SAL does not compare attribute values of individual objects searching for matchs in obs and fc fields (e.g. **MODE**), but…

- Derives attribute values of individual objects.
- Averages these values for obs and fc fields separately.
- Calculates the **difference between averaged values** of the obs and fc fields.

SAL: PROCEDURE

1) Upscale observations to model grid

2) Search of objects in forecast and observation fields separately:

Thresholding: subjetive task (visual inspection)

Rmax=P95

f=1/15

$$R^* = fR^{\max}$$

Clustering: selection of grid points belonging to an object (8 neighbors).

3) Object properties:

Rn → total pcp of the object

xn → MC

Vn → scaled volume or total pcp of the object normalized by its max value

4) Field properties:

D → domain-average pcp value in the field

V → weighted mean of objects scaled volume in the field

x → field MC

r → weighted mean of the distance between objects MCs and the field MC.

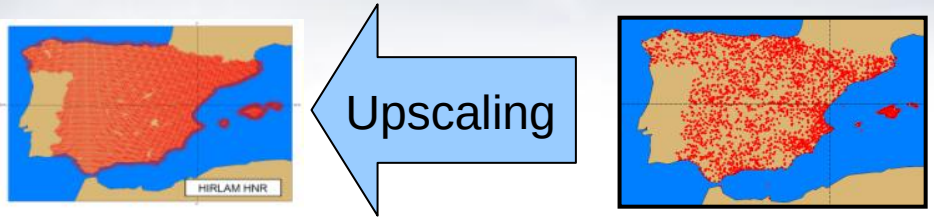
d → max distance between two points in the field

5) SAL parameters: normalized differences of field properties.

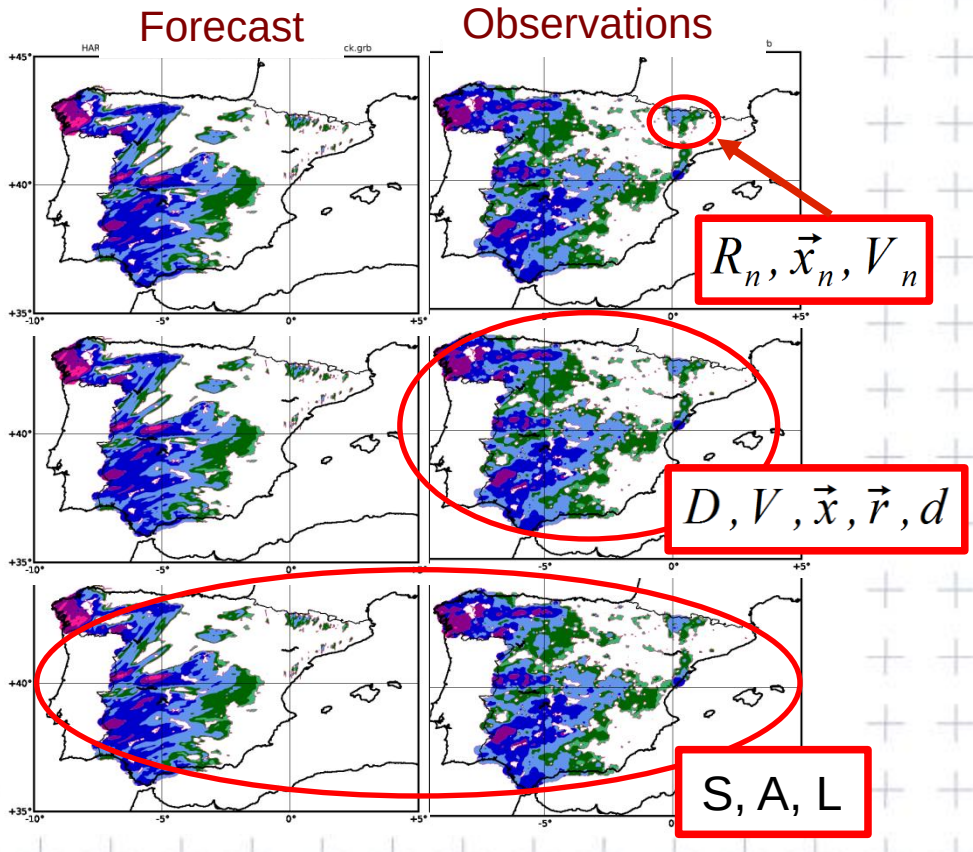
Structure → size and shape of pcp objects

Amplitude → accuracy of the total amount of pcp

Location → accuracy of the pcp distribution and relative positions of objects in the field.

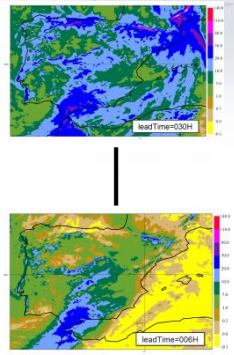


AEMET termopluvio network (3000 stations)



PyDESIGN

SSDM dataBase



ssdm

models
leadTimes 006, 030

filesAdmin

AEMET pluvioTermo Network

CRONTAB
monthly retrieval
lag: 4 months

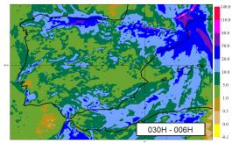
observations
obsHour 07:00

verification

030 - 006

Csv → Geo conversion

model grbFile
24hAccumPcp

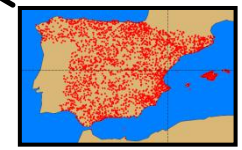


upscaled
obs. grbFile

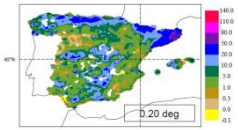
obs. geoFile
24hAccumPcp

SAL

UPS

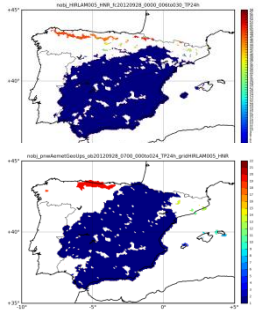


repeat N days

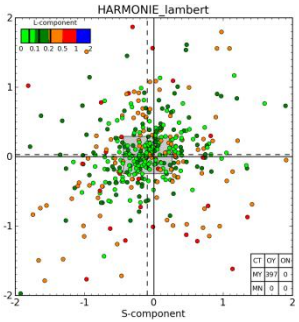


Grid template
(model file)

Objects maps

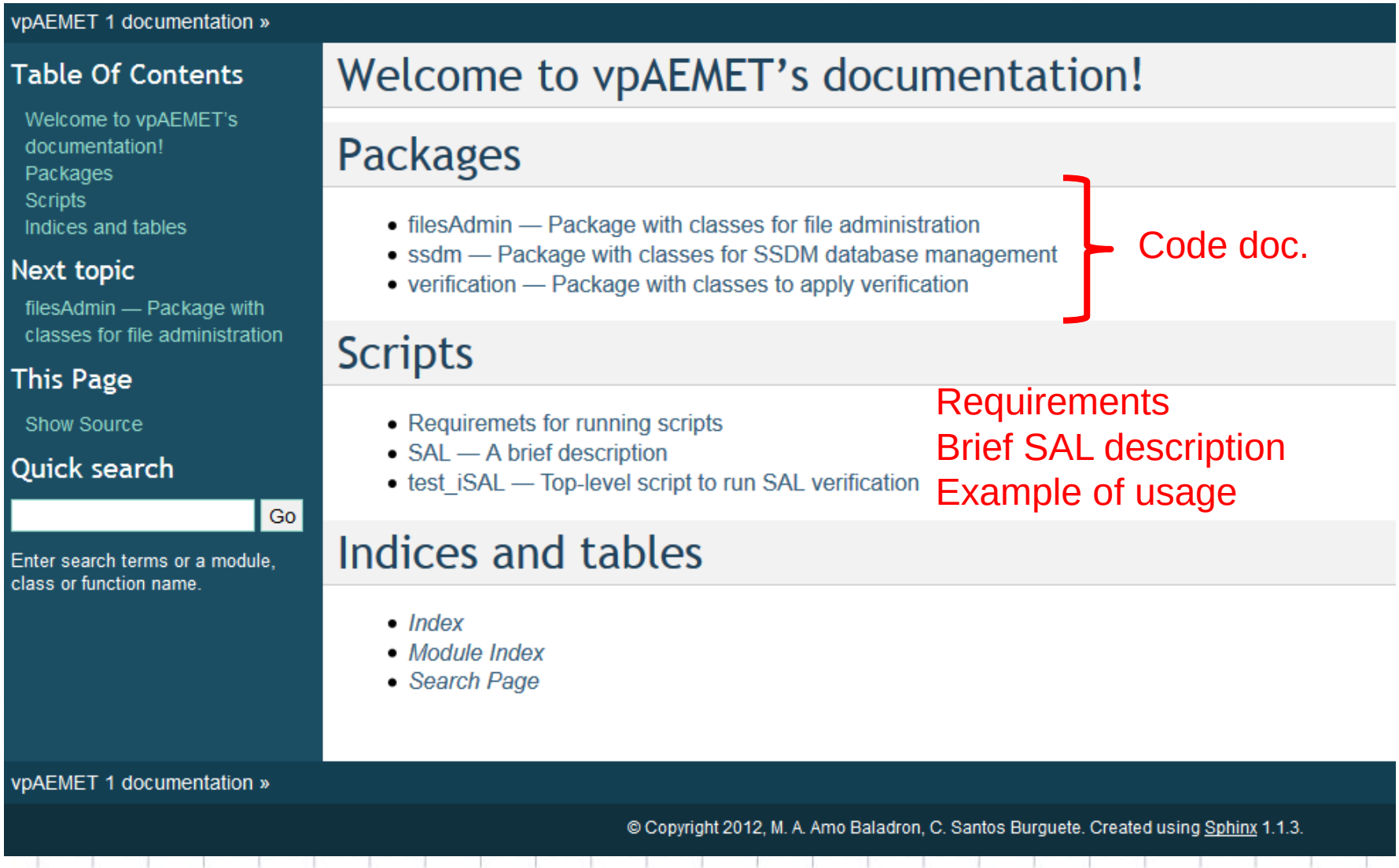


SAL plot



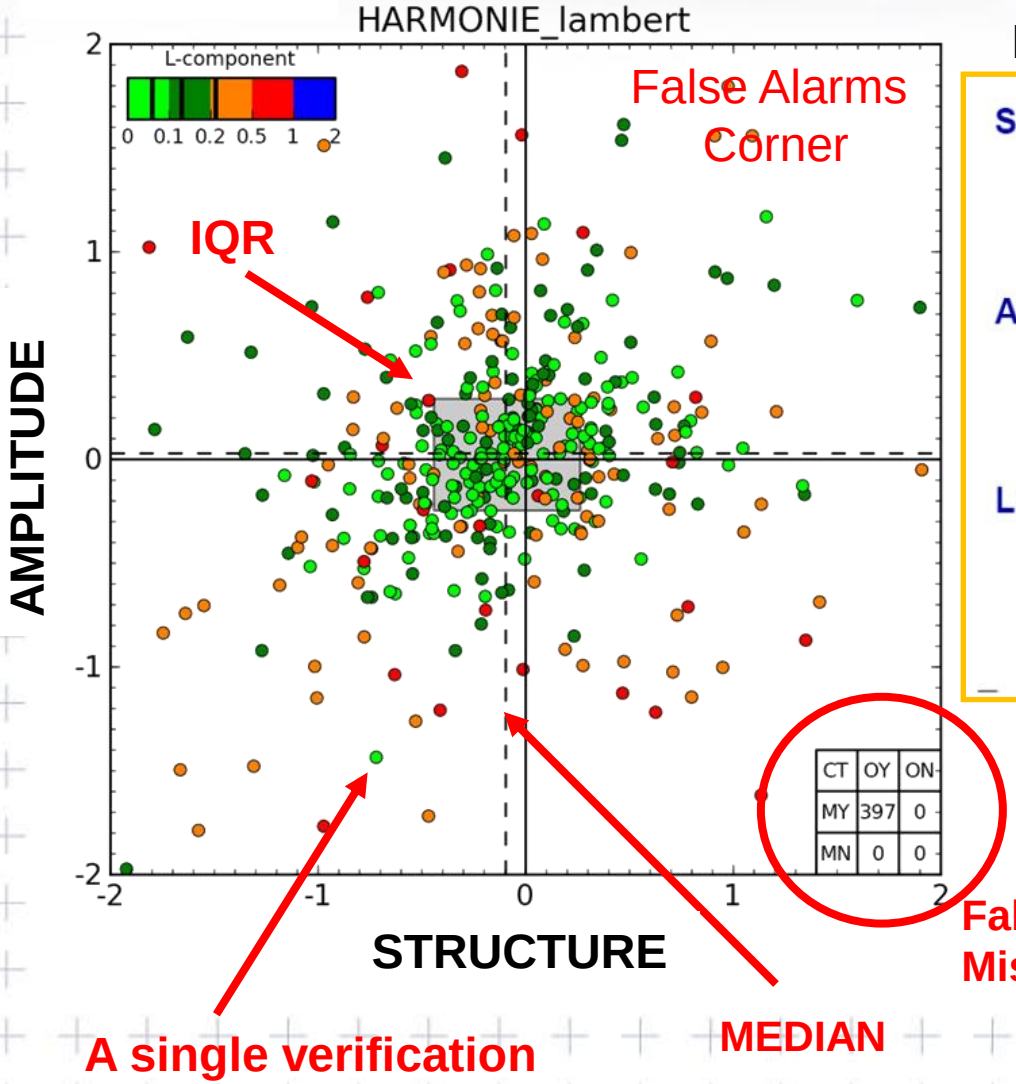
python
fortran90

CODE DOCUMENTATION



SAL PLOT

LOCATION



Model forecasts ...

S:	Structure	-2 ... objects too small or too peaked		0 Perfect		+2 objects too large or too flat
A:	Amplitude	-2 ... averaged QPF under-estimated		0 Perfect		+2 averaged QPF over-estimated
L:	Location			0 Perfect		+2 wrong location of Total Center of Mass (TCM) and / or of objects relative to TCM

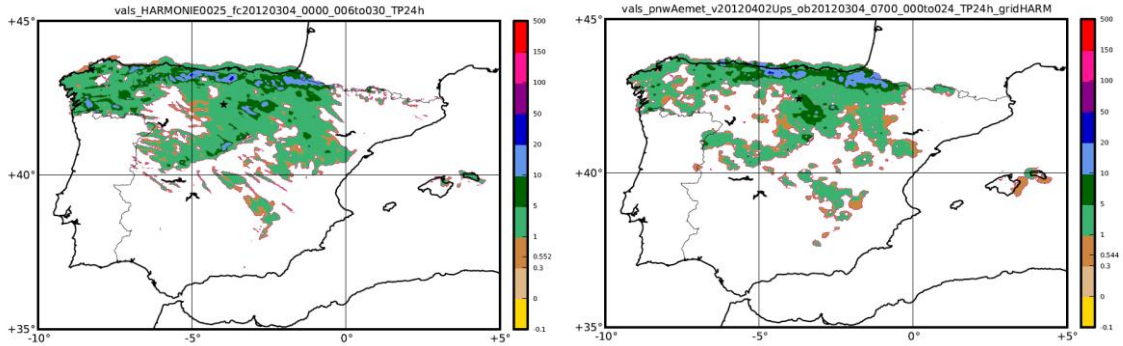
Wernli et al , 2008
SAL - A Novel Quality Measure for the Verification of Quantitative Precipitation Forecasts.
Mon. Wea. Rev., **136**, 4470–4487

SAL RESULTS

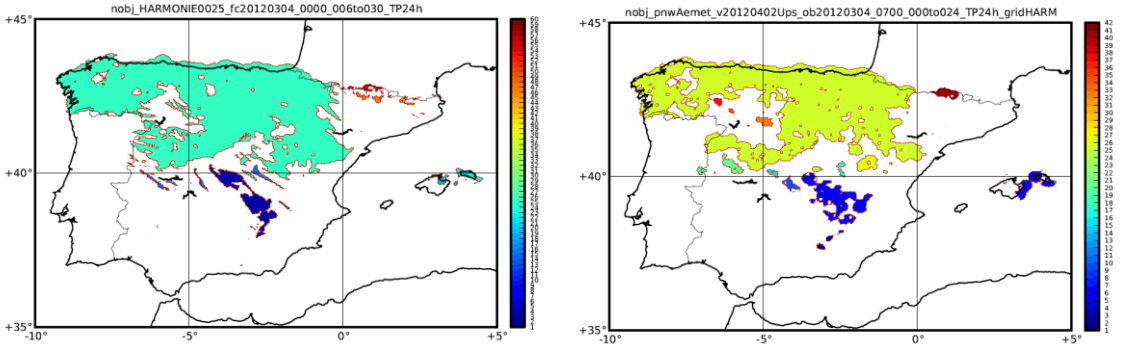
SAL RESULTS FILE

date	coMOx	coMOy	coOBx	coOBy	…	ME(bias)	MSE
20111001	346.65	144.47	337.07	174.37	…	0.006	1.034
20111002	309.40	112.80	308.45	213.23	…	-0.031	0.600
20111003	118.58	248.71	346.98	248.85	…	-0.001	0.001
20111004	227.01	186.42	102.23	298.55	…	0.015	0.071
20111005	229.13	311.49	87.69	344.59	…	-0.000	0.007
20111006	214.25	328.49	225.82	331.65	…	-0.004	2.144
…							

PCP MAPS FOR EACH VERIFICATION



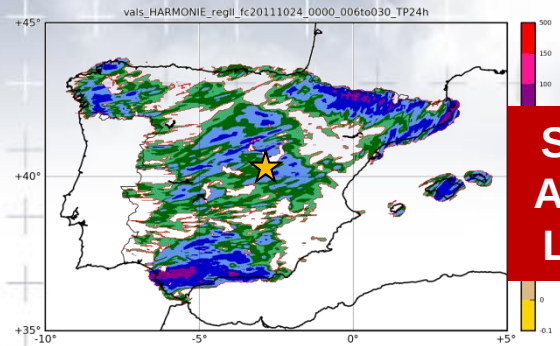
OBJECT MAPS



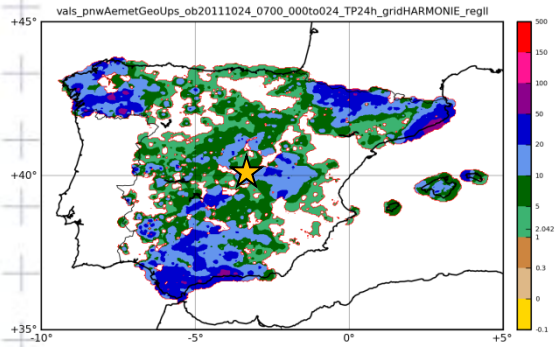
FORECAST

OBSERVATION

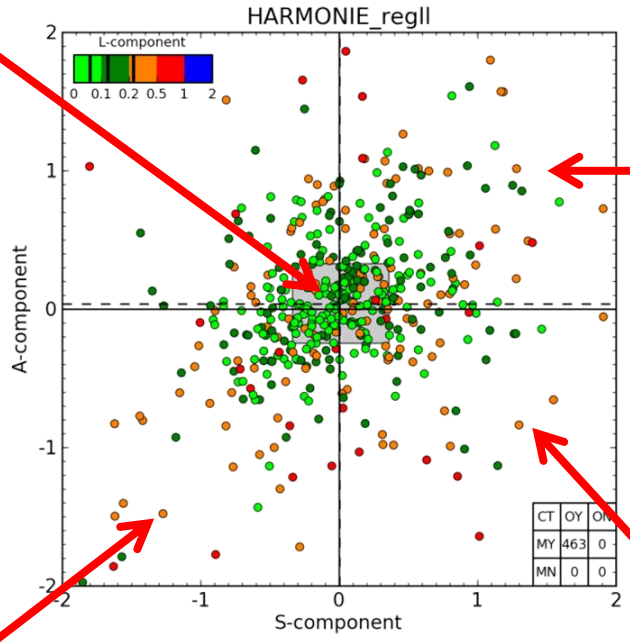
HARMONIE (2.5km)

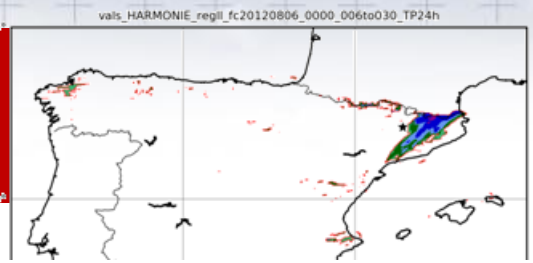


S = 0.09
A = -0.09
L = 0.05

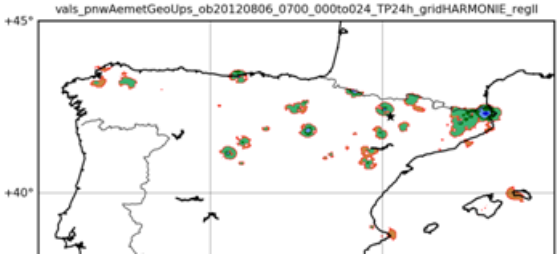


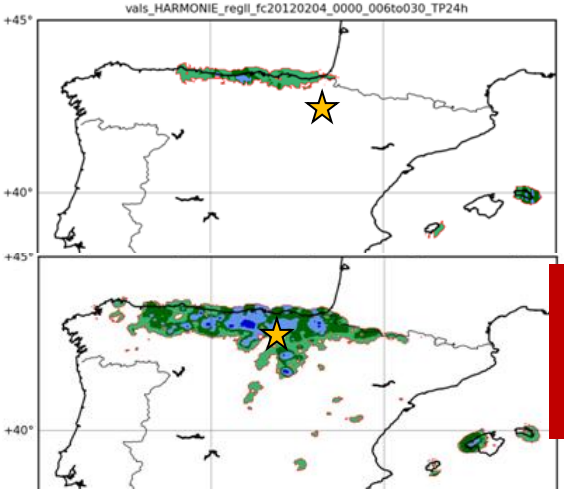
MODEL
OBSERVATION



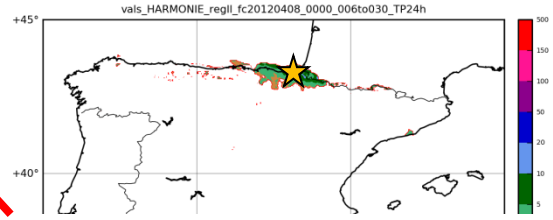


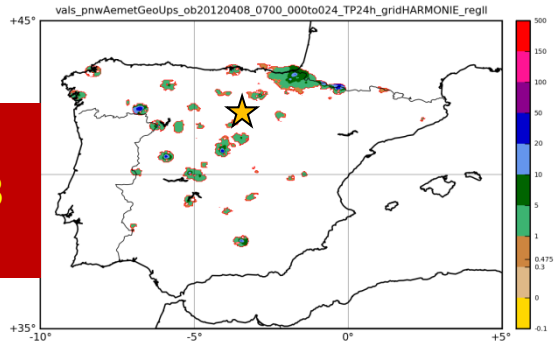
S = 1.3
A = 1.0
L = 0.3





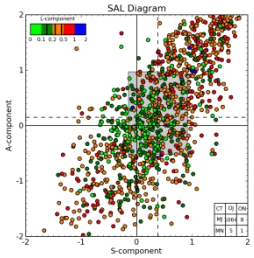
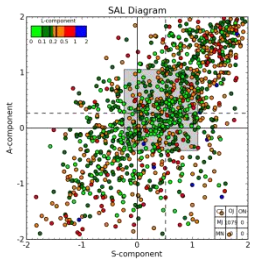
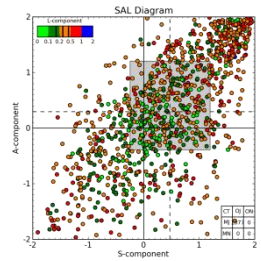
S = -1.3
A = -1.5
L = 0.5



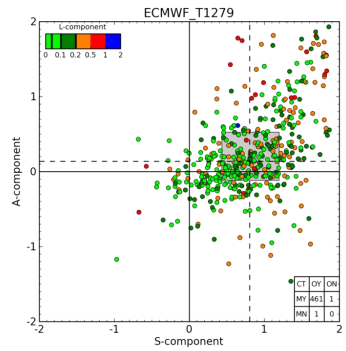
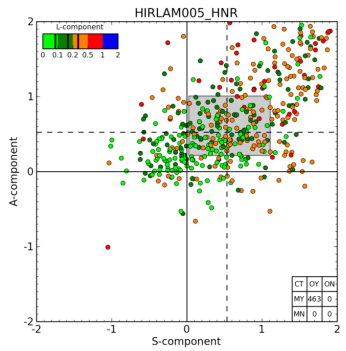
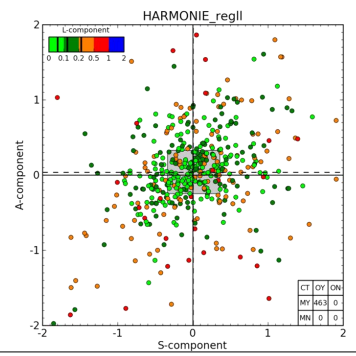


S = 1.3
A = -0.8
L = 0.5

VERIFIED PERIODS

	ECMWF T799 (0.25º)	ONR (0.16º)	HNR (0.05º)
2007 2010			

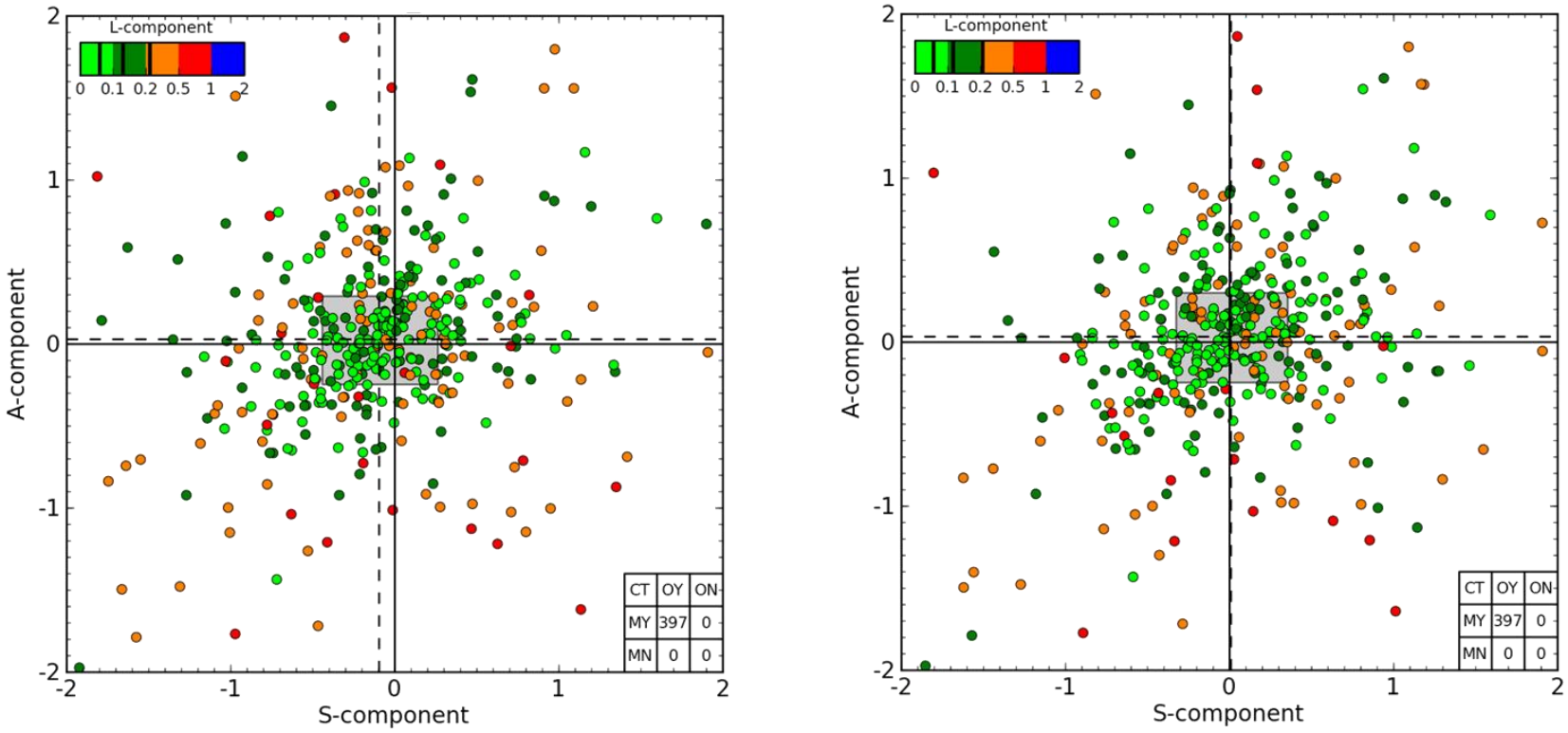
XXXII Jornadas Científicas de la AME

	ECMWF T1279 (0.125º)	HNR (0.05º)	HARMONIE (2.5km)
Oct 2011 Jan 2013			

GRID INTERPOLATION

Oct2011-Jan2013 HARMONIE (2.5km)

LAMBERT GRID → **REGULAR LATLON GRID**



S changes slightly → objects in model field are smoothed due to **interpolation**

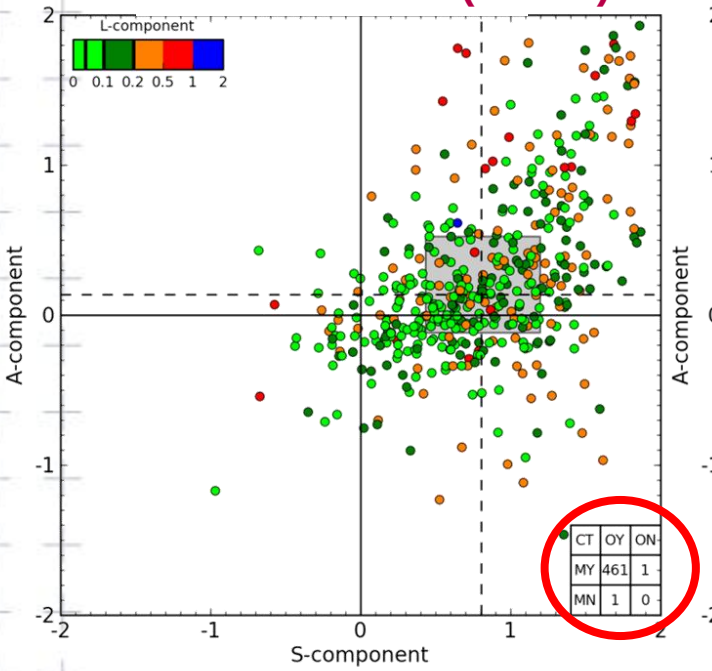
S = -0.09
A = 0.03
L = 0.13

S = 0.008
A = 0.03
L = 0.12

MODEL COMPARISON

Oct2011-Jan2013

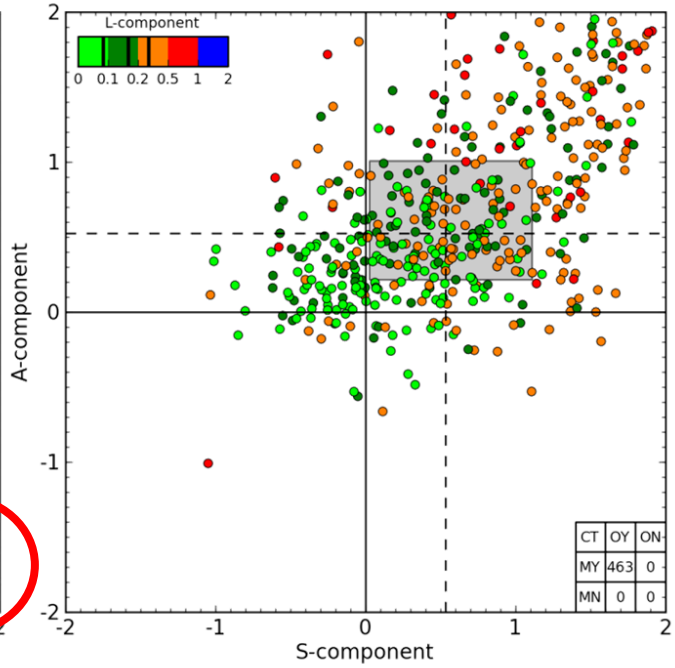
ECMWF T1279 (0.125º)



S = 0.8
A = 0.14
L = 0.10

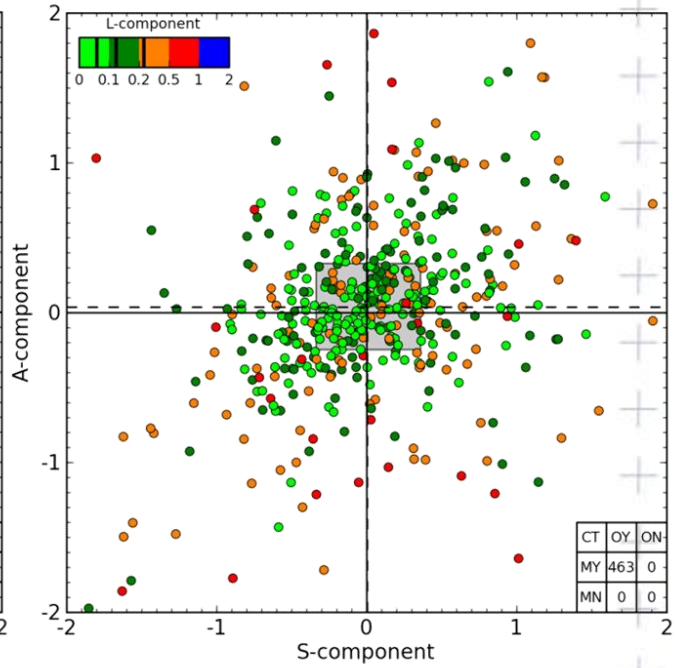
1 False Alarm
1 Missing Event

HNR (0.05º)



S = 0.5
A = 0.5
L = 0.17

HARMONIE (2.5km)



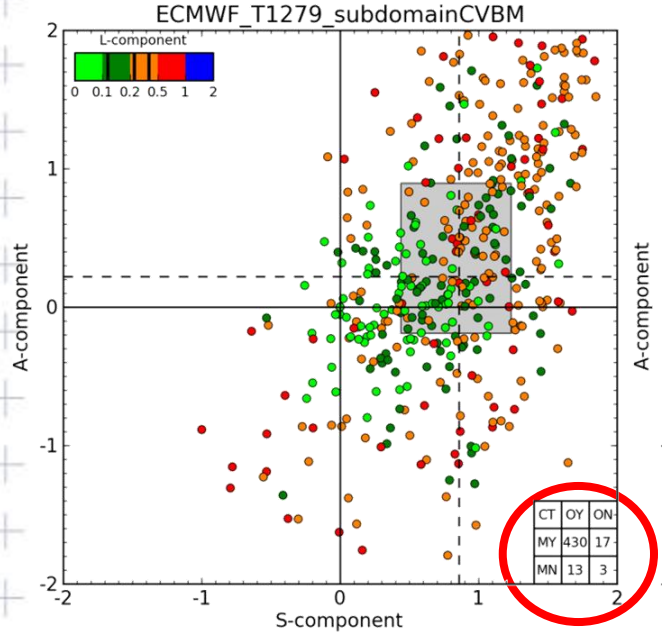
S = 0.006
A = 0.04
L = 0.12

- S → improvement at higher resolutions
- A → not correlated with resolution.
- L → without significant variability with resolution

MODEL COMPARISON

Oct2011-Jan2013: subdomain CVBM

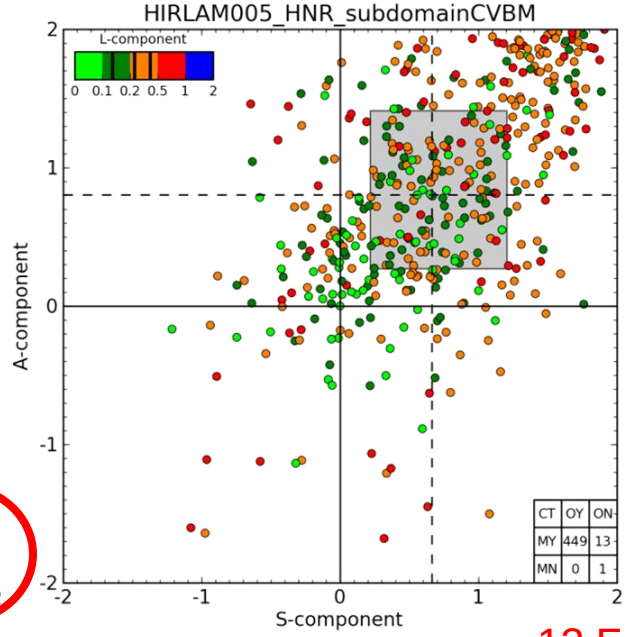
CE T1279 (0.125º)



S = 0.9
A = 0.22
L = 0.25

17 False Alarms
13 Missing Events

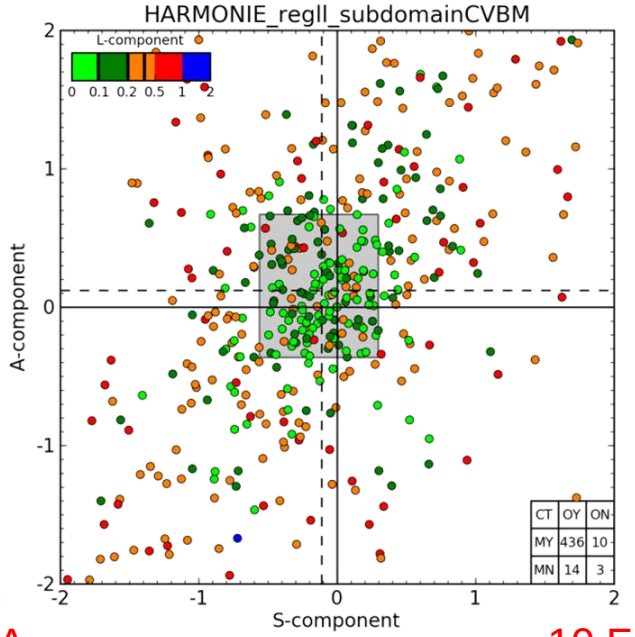
HNR (0.05º)



S = 0.7
A = 0.8
L = 0.25

13 FA
0 ME

HARMONIE (2.5km)



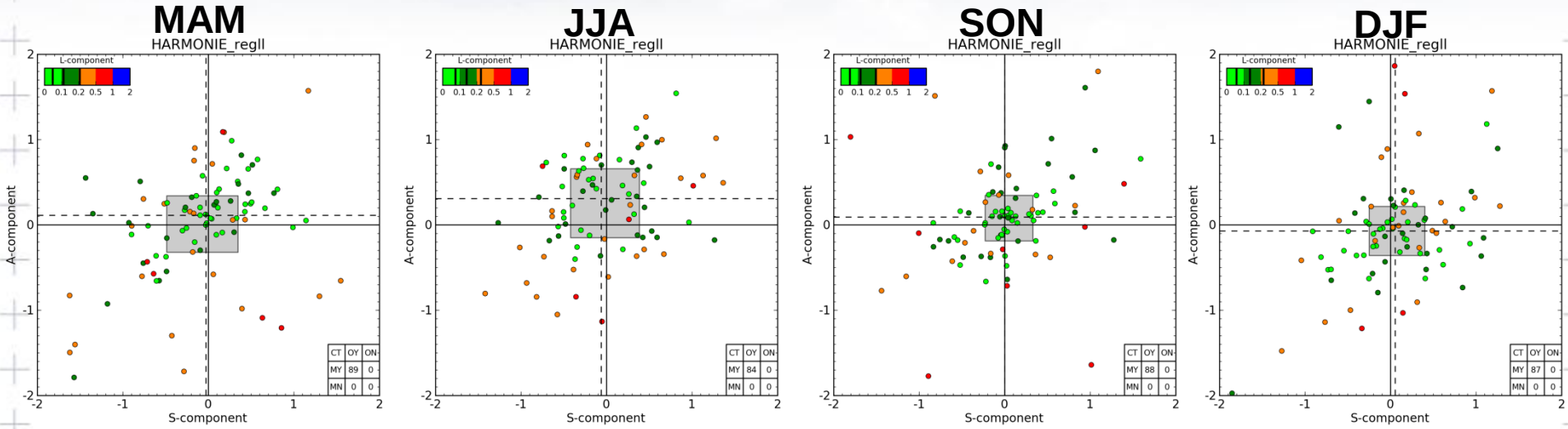
S = -0.11
A = 0.12
L = 0.21

10 FA
14 ME

SAL parameters present higher values but same tendencies as in the whole domain

Seasonal variability 2011/12

HARMONIE (2.5 km)



		MAM	JJA	SON	DJF
HARMONIE (2.5 km)	S A L	-0.03 0.11 0.11	-0.06 0.3 0.14	0.002 0.09 0.12	0.06 -0.07 0.14
HNR (0.05º)	S A L	0.4 0.6 0.14	1.1 0.9 0.20	0.7 0.4 0.15	0.5 0.6 0.14
ECMWF T1279 (0.125º)	S A L	0.8 0.24 0.10	1.0 0.5 0.10	0.8 0.009 0.11	0.9 0.20 0.14

SUMMARY

- **SAL software framework finished:**
  - Upscaling observations to grid models.
  - Retrieving forecast fields from SSDM AEMET database.
  - Providing SAL plots + objects maps for single verifications.
  - Supports Lambert conformal projection (gribApi 10.0) and rotated grids.
  - Allowing to generate SAL results for selected subdomains.
  - Code documentated with Sphinx.

- **Comparison of forecast quality using SAL method:**
  - **2007-2010**: HIRLAM (HNR 0.05º,ONR 0.16º) and ECMWF T799 (25 km).
  - **Oct2011-Jan2013**: HNR, ECMWF T1279 (16 km), and HARMONIE (2.5 km).

- **SAL solves double penalty** problem and provides **quantitative, detailed, and explicit information** about different aspects of forecast performance; allowing **fair comparisons** between models of different resolutions.

CONTRIBUTIONS

- Oral contribution: *Nuevos metodos de verificacion de las predicciones numericas de precipitacion: metodo SAL aplicado a la mesoescala.* A. Amo and C. Santos.
  XXXII Jornadas Científicas de la Asociación Meteorológica Española (AME).
  28-30 de Mayo de 2012. Alcobendas, Madrid.

- *Influence of targeted observations on short-term forecasts of high-impact weather events in the Mediterranean.*
  J. Campins, B. Navascués, C. Santos, and A. Amo

- *Long-term verification of HIRLAM and ECMWF forecasts over Southern Europe. History and perspectives of Numerical Weather Prediction at AEMET.*
  B. Navascués et al. Atmospheric Research 125-126 (2013) 20–33


THANK YOU

BONUS

SAL: measured aspects of forecast quality (I)

- **AMPLITUDE A**

Normalized difference of the domain-average pcp values between obs and fc fields.

Measure of **quantitative accuracy** of the **total amount of pcp** in the region.

A[-2,2]

A = 0 total agreement

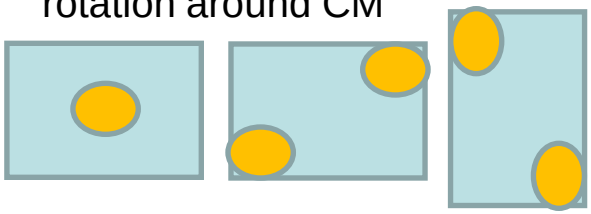
A > 0 model overestimates

A < 0 model underestimates

$$A = \frac{D(R_{\text{mod}}) - D(R_{\text{obs}})}{0.5[D(R_{\text{mod}}) + D(R_{\text{obs}})]}.$$

$$D(R) = \frac{1}{N} \sum_{(i,j) \in \mathcal{D}} R_{ij},$$

Not sensitive to rotation around CM



$$L_1 = \frac{|\mathbf{x}(R_{\text{mod}}) - \mathbf{x}(R_{\text{obs}})|}{d},$$

$$r = \frac{\sum_{n=1}^{M} R_n |\mathbf{x} - \mathbf{x}_n|}{\sum_{n=1}^{M} R_n}.$$

- **LOCATION L=L1+L2**

L1→ Normalized distance between the CM of the obs/fc pcp fields

First order indication of the **accuracy** of **the pcp distribution**

$$L_2 = 2\left[\frac{|r(R_{\text{mod}}) - r(R_{\text{obs}})|}{d}\right].$$

L2 → Takes into account the average distance between the CM of the total pcp field and infividual pcp objects → **relative positions** of objects in the field.

L[0,2] with **L = 0** → CM and average distance objects-CM are equal in obs and fc fields

SAL: measured aspects of forecast quality (II)

- **STRUCTURE S**

Compare the volume of the normalized pcp objects. $V_n = \sum_{(i,j)\in \mathcal{R}_n} R_{ij}/R_n^{\max} = R_n/R_n^{\max},$

Information about **size and shape** of objects.

Individual object volume → total pcp of the object normalized by its max value.

A weighted mean of all objects pcp volume is calculated for obs and fc fields.

$$V(R) = \frac{\sum_{n=1}^{M} R_n V_n}{\sum_{n=1}^{M} R_n}. \qquad S = \frac{V(R_{\text{mod}}) - V(R_{\text{obs}})}{0.5[V(R_{\text{mod}}) + V(R_{\text{obs}})]}.$$

S → normalized difference between obs and fc weighted mean volumes.

S[-2,2]

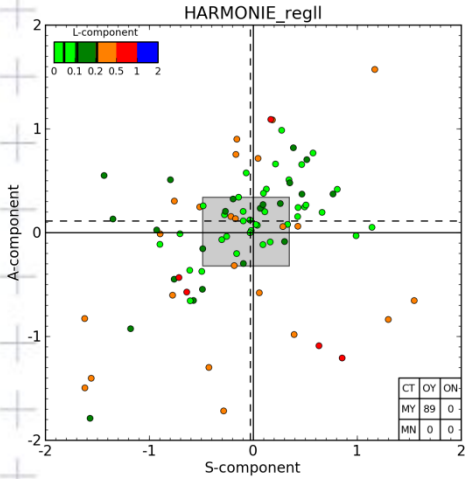
S >> 0 → model predicts **widespread pcp** but observations show small convective events

S << 0 → model predicts **small and/or picked pcp** objects compare to observations

Seasonal variability 2011/12

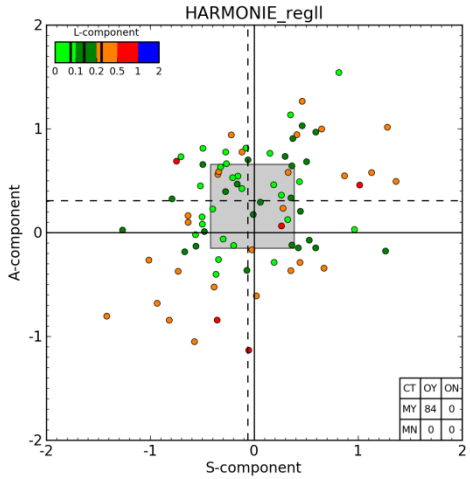
HARMONIE (2.5 km)

MAM



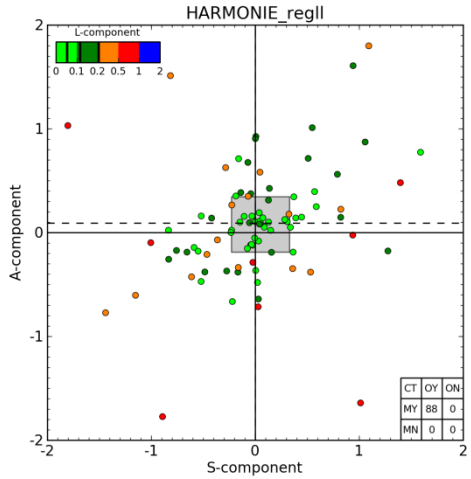
S = -0.03
A = 0.11
L = 0.11

JJA



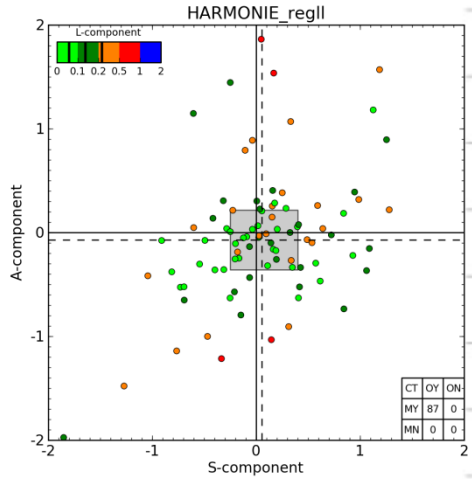
S = -0.06
A = 0.3
L = 0.14

SON



S = 0.002
A = 0.09
L = 0.12

DJF

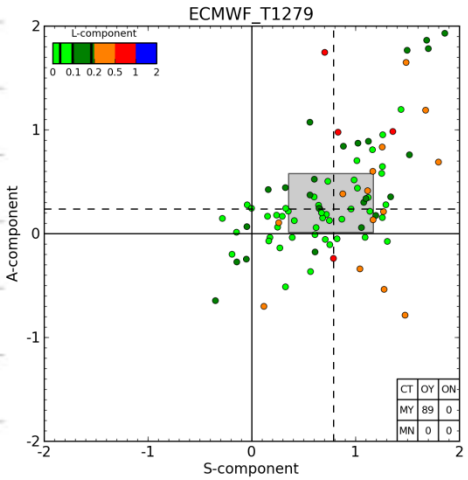


S = 0.06
A = - 0.07
L = 0.14

Seasonal variability 2011/12

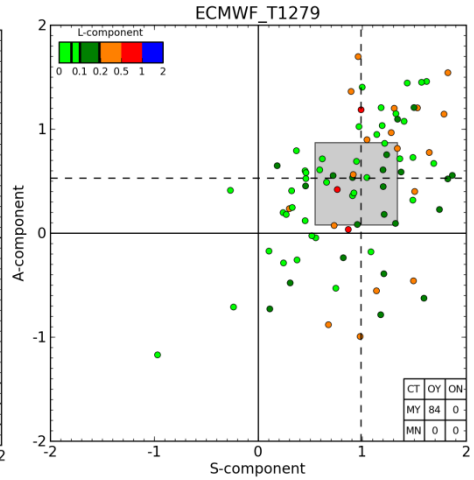
ECMWF T1279 (0.125º)

MAM



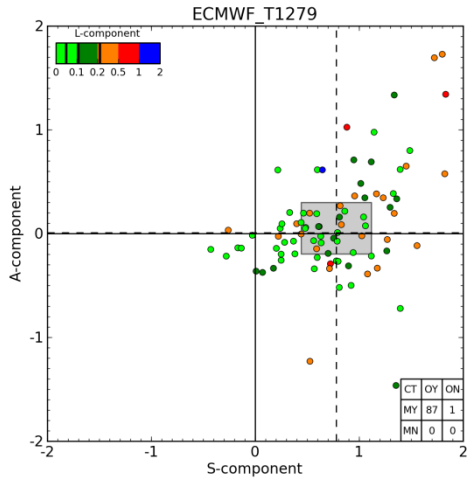
S = 0.8
A = 0.24
L = 0.10

JJA



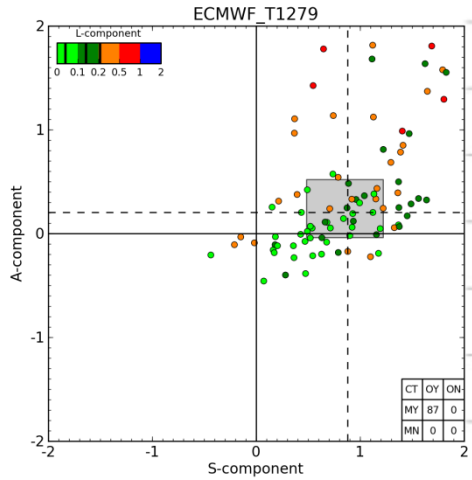
S = 1.0
A = 0.5
L = 0.10

SON



S = 0.8
A = 0.009
L = 0.11

DJF

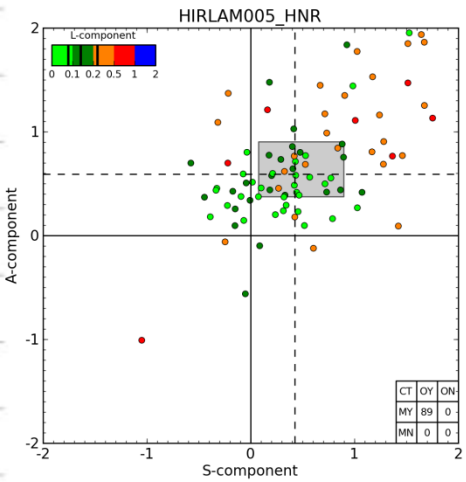


S = 0.9
A = 0.20
L = 0.14

Seasonal variability 2011/12

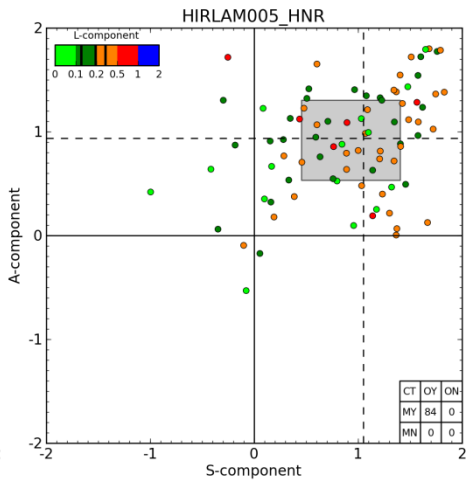
HNR (0.05º)

MAM



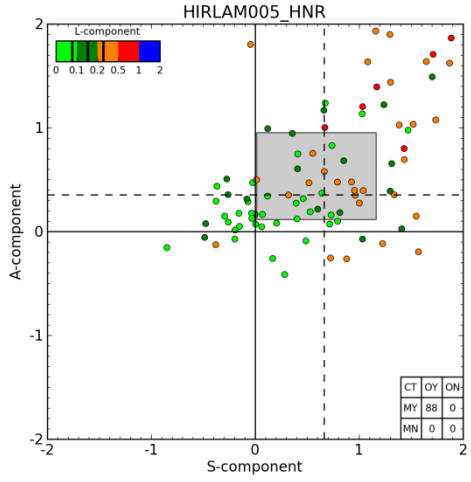
S = 0.4
A = 0.6
L = 0.14

JJA



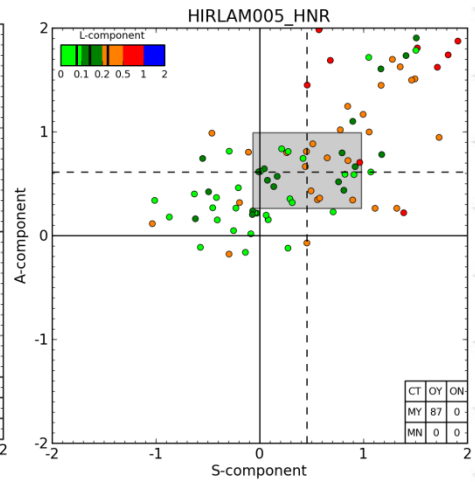
S = 1.1
A = 0.9
L = 0.20

SON



S = 0.7
A = 0.4
L = 0.15

DJF



S = 0.5
A = 0.6
L = 0.14